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I, LEANNE MYNOTT, MANAGER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2004903440 for a patent by SUSTAINABLE TECHNOLOGIES INTERNATIONAL PTY LTD as filed on 24 June 2004.



WITNESS my hand this  
Twelfth day of November 2004

A handwritten signature in black ink, appearing to be "LM" or "Leanne Mynott".

LEANNE MYNOTT  
MANAGER EXAMINATION SUPPORT  
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## PROVISIONAL SPECIFICATION

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INVENTION TITLE: Photovoltaic device with improved angular performance

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TECHNICAL FIELD

This invention relates to the photovoltaic devices and sensors, materials and methods used for electrical  
5 connections for such devices, in particular, to materials and methods used for fabrication of such devices,

More particularly this invention relates to the thin film photovoltaic devices and especially to nano-particulate  
10 photo-electrochemical (PEC) devices including sensors and photovoltaic cells. Examples of the nano-particulate PEC devices are disclosed in the following patents and applications:

15 US4927721, Photoelectrochemical cell; Michael Graetzel and Paul Liska, 1990.

US5525440, Method of manufacture of photo-electrochemical cell and a cell made by this method; Andreas Kay, Michael  
20 Graetzel and Brian O'Regan, 1996.

US6297900, Electrophotochromic smart window; Gavin Tulloch and Igor Skryabin, 2001.

25 PCT/AU01/01354, UV sensors and arrays and methods to manufacture thereof, George Phani and Igor Skryabin

BACKGROUND TO THE INVENTION

30 PEC cells, as of the type disclosed in the above patterns, are capable of being fabricated in a laminate arrangement between two substrates without undue expense. In another arrangement these devices are capable of being fabricated

on a single substrate by subsequent deposition of device layers.

When a PEC device is fabricated between two substrates, at least one substrate is required to be substantially  
5 transparent to solar radiation.

One typical arrangement involves two glass substrates, each utilising an electrically conducting coating upon the  
10 internal surface of the substrate. Another typical arrangement involves the first substrate being glass or polymeric and utilising an electrically conducting coating upon the internal surface of the substrate, with the second substrate being polymeric. In some arrangements,  
15 the internal surface of said second polymeric substrate is coated with an electrically conducting coating, whereas in other arrangements, said second polymeric substrate comprises a polymeric foil laminate, utilising adjacent electrically conductive material, such as carbon. Also, in  
20 some arrangements, the external or internal surface may be a laminated metal film, and in other arrangements, the external or internal surface may be coated by a metal. At least one of said first and second substrates is substantially transparent to visible light, as is the  
25 attached transparent electrically conducting (TEC) coating. PEC cells contain a photoanode, typically comprising a ruthenium dye-sensitised, nanoporous semiconducting oxide (eg. titania) layer attached to one conductive coating, and a cathode, typically comprising a  
30 redox electrocatalyst layer attached to the other conductive coating or conductive material. An electrolyte containing a redox mediator is located between the photoanode and cathode, and the electrolyte is sealed from

the environment. If one or more polymer substrates are utilised, the photoanode and the cathode are typically electrically separated by a porous insulating layer (eg. insulating ceramic oxides) or spacer(s) (eg. insulating spheres). TEC coatings, which usually comprise a metal oxide(s), have high resistivity when compared with normal metal conductors, resulting in high resistive losses for large area RPEC cells operating under high illumination. When operating under high illumination, one method to minimise these losses is the deposition of one or more networks of electrically conductive material that serve to collect and/or distribute electrons in the cell. Another method to minimise these losses is by connecting a multiple of PEC cells (here called 'PEC modules') in series to generate higher voltages and to minimise total current. Such connections in RPEC modules may be made externally or internally (International Application PCT/AU00/00190). To enable internal series connection of adjacent RPEC cells, selected areas of such conducting coatings must be electrically isolated, portions of such areas overlapped when laminated, interconnects used to connect such overlapped areas and electrolyte-impermeable barriers used to separate the electrolyte of individual cells.

25

One example of the manufacture of an PEC module involves the use of two glass substrates that have TEC-coatings that have been divided into electrically isolated regions. Titanium dioxide (or similar semiconductor) is screen printed onto selected areas of the TEC coating of one substrate and an electrocatalyst is screen printed onto selected areas of the TEC coating of the other substrate. The titanium dioxide (titania) is coated with a thin layer

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of a dye by immersion of the titania-coated substrate in the dye solution. Strips of sealant and interconnect material are deposited upon one of the substrates and the two substrates are then bonded together. Electrolyte is added to the cells via access apertures in one of the substrates and these apertures are then sealed.

Another example of the manufacture of a PEC module involves the use of one substrate with a TEC-coating that has been divided into electrically isolated regions. Successive layers of titania, insulating ceramic oxide, and conducting catalytic material (for example, carbon-based) are deposited, for example by screen printing, onto selected areas of the TEC-coated substrate, with the catalytic layer also serving as an interconnect. The titania is coated with a thin layer of the dye by immersion of the multiple-coated substrate in the dye solution. Electrolyte is added to the spaces within the porous titania-insulator-catalytic layers. The sealant face of a sealant/polymer and/or metal foil laminate is sealed to the substrate.

One advantage of PEC devices described above is in better than of conventional solid state device angular performance. It has been demonstrated that these devices perform well even under diffuse light conditions or when solar angle of incidence differs from normal. This advantage is attributed to nano-particulate structure of photo-active layers, that provides high area of photoactive surface. Each nano-particle, coated with thin layer of dye absorbs light incident from all directions, thus improving angular performance for a whole cell.

Unfortunately, these advantages of PEC are reduced by necessity of utilizing substantially planar substrates. An interface between a planar substrates and air reflects significant part of solar energy at low angles of incidence. Antireflective coatings could overcome this problem only partially; their antireflective properties are typically wavelength dependent, thus optimized for only small part of solar spectra.

In addition, the said PEC devices, especially of large size require highly conductive and simultaneously transparent coating. Electrical resistance of transparent electrical conductors is often a limiting factor for performance of devices larger than 5-10mm.

#### OBJECTIVES OF THE INVENTION

It is therefore an object of the present invention to provide a thin film PV device, more particularly - a photoelectrochemical device with improved performance by minimizing ohmic losses on transparent conductor and improving utilization of light at all angles of incidence and more specifically - utilization of diffuse light.

It is further object of the invention to provide for self-sustainable sensor and communication device.

#### SUMMARY OF THE INVENTION

The invention provides for the photovoltaic (PV) device that comprises a plurality of photovoltaic cells each formed on a face of a many-sided geometrical shape.

To minimize ohmic losses each face is relatively small.

From one aspect of the invention, a PV device comprises a plurality of PV cells each formed on faces of a regular polyhedron.

- 5 From another aspect of the invention the said many-sided geometrical shape is enclosed by a transparent curved shape. In this case solar radiation incident to the external curved shape is transmitted without significant losses to the faces of the said multi-sided shape.

10

In one embodiment the said external curved shape is substantially spherical.

- 15 In another embodiment, material of the curved shape is selected in such a way that its refractive index is matching that of the top substrate of the PV cell, thus minimizing losses on the interface between the PV cells and the curved enclosure.

- 20 In yet further embodiment, the enclosure is made of a rubbery material.

- From yet another aspect of the invention, the said multi-faced shape is hollow. In one embodiment, an internal  
25 device(s) is(are) placed inside the shape and electrical energy generated by the PV cells is used for operation of these internal devices. Electrical connections are made between the PV cells and the internal device(s).

- 30 In one embodiment the said internal device is an energy storage device.



In another embodiment the said internal device is a communication device.

In yet another embodiment the said internal device is a  
5 sensor device (e.g. optical, acoustic, radiation)

In further embodiment the said internal device is partially extended to outside of the enclosure and sensor is mounted on the enclosure to monitor changes in the  
10 environment (e.g. chemical, temperature)

In yet another embodiment, the said internal device is partially extended to the enclosure to provide antenna for data communication.  
15

In further embodiment, one of the faces of the multi-sided shape could be open/closed in a door-like manner, so an electronic device could be placed inside the shape.

20 In yet further embodiment, the space inside the multi-faced shape is filled with a rubbery material. In one example, the internal device is placed inside the multi-faced shape and connected to the PV cells; following that the space inside the multi-faced shape is filled with a  
25 material in the liquid form; this material after an appropriate curing is transformed into solid form (e.g.- polyurethane).

In yet further embodiment the said internal device  
30 comprises electrical diodes.

From further aspect of the invention the said PV cells are DSC cells.

In one embodiment the DSC cells are made on flexible substrate and preshaped (cut) to a shape that is similar to a face of the multi-faced shape.

5

In another embodiment, the DSC cells are fabricated on metal foil.

10 In yet another embodiment, two or more cells are placed on a face of the said multi-faced shape. The cells may be interconnected, such as the face produces electrical voltage higher than that of an individual photovoltaic cell.

15 In further embodiment the DSC cells are fabricated on plastic substrate.

In yet further embodiment a face of the multi-faced shape serves as a substrate for DSC cell.

20

From yet further aspect of the invention the multi-faced shapes include communication devices. The shapes are dispersed and form a communication network.

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#### **BRIEF DESCRIPTION OF DRAWINGS**

30 Having broadly portrayed the nature of the present invention, embodiments thereof will now be described by way of example and illustration only. In the following description, reference will be made to the accompanying drawings in which:

Figure 1 is an 3D representation of a regular multi-faced shapes suitable for the purpose of this invention.

5        Figure 2 is a 3D representation of a device in accordance with 1<sup>st</sup> example of the invention.

#### DETAILED DESCRIPTION OF DRAWINGS

10        Referring to Fig.1 various multi-faced shapes are suitable for purpose of the invention, including regular polyhedron.

Referring to Fig. 2, the 1<sup>st</sup> example of this invention  
15        comprises photovoltaic cells 3 formed on each of 6 faces of a cubical shape 1. The front face of the shape is not shown. The cubical shape is placed inside a spherical transparent enclosure 2 (polyurethane). An energy storage device 4 (Li rechargeable battery) is placed inside the  
20        cube and electrically connected to each of the photovoltaic cells. The energy storage device include electrical semiconducting diodes (not shown) to separate the photovoltaic cells electrically from each other and to prevent discharging of the energy storage device through  
25        the photovoltaic devices. In addition a sensing device 5 is placed inside the cube. The sensing device (temperature sensor) is extended to outside of the enclosure to ensure that a sensor 6 is at temperature of the surrounding environment. Communication device 7 receives data from the  
30        sensing device and after preliminary data treatment transfers it with aid of an antenna 8. The sensing device and the communication device are both powered by the energy storage device. The cubic shape is filled with a

rubbery material 9. The rubbery material ensures that all  
the devices within the cubic shape are mechanically  
attached to the shape. Both the internal rubbery filler  
and the enclosure ensure mechanical ruggedness of the  
5 device.

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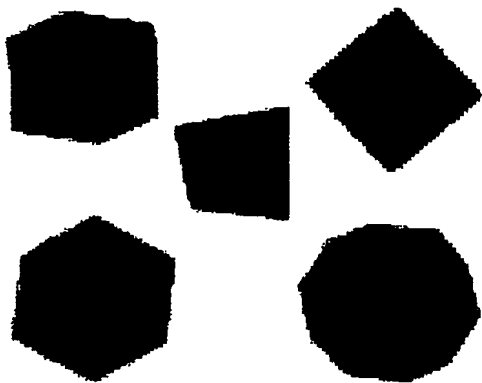


Figure 1. Regular multi-faced shapes suitable for the purpose of the invention. Each face of the shapes is a photovoltaic cell.

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